Schematic vs. Topographic Maps in Pedestrian Navigation: How Much Map Detail is Necessary to Support Wayfinding

Georg Gartner and Verena Radoczky
Cartography and Geo-Mediatechniques
Department of Geoinformation and Cartography
Technical University Vienna
Erzherzog-Johannplatz 1
A-1040 Vienna, Austria
georg.gartner@tuwien.ac.at
radoczky@mail.zserv.tuwien.ac.at

Abstract

Until today maps have proven to be a very efficient presentation form when communicating route information to people. Yet many different types of maps, with different styles and different extent, are used without any evidence about their auxiliary qualities in wayfinding. Traditional city maps contain a lot of detail and could therefore overload the user with information. Possibly the user gets distracted and is hindered in his wayfinding task. Schematic maps, on the other hand, usually lack information that could help a pedestrian to find his way. Presumingly the most helpful information source for pure navigation purposes is a cross of a topographic and a schematic map.

This submission describes current efforts at the Technical University of Vienna to prove the effectiveness of certain levels of map abstraction for route communication in pedestrian navigation systems.

1 Introduction

In order to provide efficient wayfinding services for Location Based Services (LBS), it is inevitable to investigate different possibilities on how to visualise route information. The most common medium when communicating spatial information is the map. Many other techniques, like virtual or augmented reality, are imaginable today but they could not replace cartographic representations until today. Their capability of conveying good overviews of the area in question are unrivalled until today. Yet many different types of maps are available. They are designed in different styles and contain different levels of detail. Usually a lot of information is displayed on a comparably small sheet of paper, which could hinder information extraction when reading the map. But how much detail is actually needed to guarantee wayfinding success? In some situations schematic maps, like the famous London Underground map, contain enough information to easily find a certain destination, but when moving through a city as a pedestrian, these depictions might not contain enough detail to stay on the right track.

Within the scope of the project NAVIO (pedestrian NAVigation in combined Indoor / Outdoor environments), which is funded by the Austrian Science Fund, different levels of map abstraction are investigated regarding their potential in specific user situations. Since this submission describes work in progress that will be examined within the following months, no detailed results can be presented yet, but ideas and concepts are introduced that should demonstrate the efforts that have been involved in this issue so far.

The submission is therefore organised as follows: Section 2 investigates the potential of maps as wayfinding aids, in section 3 schematic and topographic maps are examined and their main characteristics are described. Section 4 introduces different levels of abstraction that differentiate schematic from topographic maps, and section 5 describes current efforts on this issue.

2 Maps as Wayfinding Aids

Maps are generally the most important presentation form when communicating route information. Even though nowadays new techniques like virtual and augmented reality, animation and many other multimedia tools are imaginable, cartographic representations are still the best form of giving an overview of an area. Provided that directions are indicated with arrows on the map, tests with mobile devices, which are comparably small in size, showed that even there maps are the most efficient tool for describing directions (Reichl 2003). This acknowledgement applies to all sorts of user situations, like day and night time, fog, rain or snow, quiet and noisy environments, as well as to different user groups, like tourists, natives or business travellers (Reichl 2003).

Bohnenberger & Jameson (2001), who tested a navigation system in 2 different modes in a duty free area on an airport, stated that: "…map mode will increase the likelihood that the user will find a gift, whereas speech mode will tend to make the user move faster." (Bohnenberger & Jameson 2001, pp. 22). Moreover Thorndyke & Hayes-Roth (1982) could show that people who investigate a map are better at judging air-line distances than direct navigation learners, who on their part are better at estimating route distances. This result implies that even though maps can differ dramatically from the perceived structure of a spatial environment, they can help the user to get a good overview of the area, whereas textual instructions purely concentrate on the communication of the route (Kray et al. 2003). Instinctively people typically consult maps when they have to find their way through an unfamiliar environment (Iachini & Logie 2003). This assumption is reinforced by Kray et. al. (2003) who believe that, because of their natural incorporation of contextual information, 2D maps are a well-known tool for navigation. Nevertheless, in situations where a fast response is required, it can be doubted, if maps are ideal presentation forms. Because of the high cognitive load for the user, this holds even more true when using 3D visualisations or virtual environments. However, given enough time, the added information a virtual environment may provide will increase performance (Darken & Peterson 1999).

When designing an appropriate map for navigation, it would be helpful to know when the map is used or for what tasks the map is to be used for (Darken & Peterson, 1999). Sometimes the navigation system itself can give the answer to this question. If the system includes a lot of sights as landmarks, it is probably geared to tourists, if it is situated in a public building, it is usually geared to visitors, etc. As soon as the purpose of the system is known, the content of the represented map should be reduced to a minimum. This reduces the amount of information that needs to be processed by viewing one map (Klippel, 2003).

3 Schematic and Topographic Maps

Schematic maps are linear cartograms designed to convey only essential features of network routes (Monmonier 1996). They are maps with a specific purpose that only visualise selected aspects of reality (Klippel 1999), like subway maps where usually only line and point features can be found. When looking at schematic maps, movements through complex systems can be easily traced, connections quickly compared and destinations easily located at a quick glance. Therefore we can conclude that schematic maps are graphic representations of topology, where linear features are abstracted until only their functions remain but not necessarily their location (Elroi 1988).

The creation of schematic maps allows a high degree of individuality to the user. A high level of abstraction can be applied when generating a schematic map. From one single topographic map an inexhaustible set of schematic maps can be derived (Klippel 2003), because the theme of the new depiction could differ dramatically and because there are no specific design goals on how to construct schematic maps. Still, typically the following 3 steps are applied in order to generate a schematic depiction (Elroi 1988):

Figure 1: Schematic Map of Public Transport in Vienna (www.wienerlinien.at)

1. Simplification of lines to their most elementary shapes
2. Re-orientation of lines to conform to a regular grid, such that they all run horizontally, vertically or at a forty-five degree diagonal
3. Expansion of scale in congested areas at the expense of scale in areas of lesser node density

Most commonly schematic maps are used to visualise transportation networks, where all relevant underground and railway lines are included and emphasis is placed on intersections. A typical example of a distorted schematic depiction is the map of the Viennese underground as can be viewed inside of each wagon (Figure 1). Due to the lack of space, north-south directions are highly compressed whereas east-west directions are stretched. Nevertheless passengers are able to extract information about the length of their journey and about when to switch trains.

It is though questionable whether this is also true whilst walking along a route with the intention of getting to a certain destination. Agrawala and Stolte (2001) describe difficulties with schematic maps amongst users, because they provide little detail outside of the main route. Especially if a navigator accidentally strays away from the route, he could have difficulties to find his way back.

Topographic maps, on the other hand, might include a lot of detail that is not needed by the user. According to the respective scale, a topographic map is a type of map, which displays all-embracing and correct information about the surface of the earth that is necessary for humans to take action and orientate on terrain (Bollmann and Koch 2002). Typically the main contents are: settlements, transportation routes and objects, borders, waters, surface conditions and relief. City maps are a special form of topographic maps with a larger scale that usually exclude relief but instead concentrate on building blocks and streets including their names. Public buildings, historical sites, hotels, guest houses, sport and leisure sites as well as lines and stops of public transport are particularly pointed out. Here the question arises, how much detail is really needed by a pedestrian, whose aim is solely to get to a certain destination without any additional stops at sights or shops.

One possible conclusion could be that in situations with a low degree of freedom in moving, schematic maps can be regarded as a cognitive adequate information source in the wayfinding process (Agrawala and Stolte 2001), whereas in situations that offer many possibilities on how to move on, maps with more detail are required. In order to further concretise this question, the following section introduces a way on how to approach this problem.

4 Different Levels of Abstraction

Since neither topographic maps nor schematic maps seem to be ideal for communicating route information, because of their overload and respectively their lack of information, a medium of both seems to be the obvious solution. The main problem though is to find out, which map elements are indispensable and which are unnecessary.

The basic elements of schematic maps are nodes and edges which connect them. This schema is typical for networks and is often used to represent street graphs. Presumably a schematic map like this without any additional features and without any labelling does not support the wayfinding process of pedestrians. When adding street names to this depiction, the probability that displayed places could be identified with real locations increases massively, but only when street signs are clearly visible in the urban environment. Expanding this version with elements of street graphs that are crossed or passed by, the route reveals a picture of a larger network which could help the user to comprehend coherence. The pedestrian could count the number of streets to be crossed before the next right turn, and whenever he reaches a crossing with a high node degree, the number of outgoing edges could be compared with the amount of streets leading away from a square. Again street labels could additionally help to orientate along the way.

Adding any additional features to schematic maps does probably not improve the wayfinding process. The arrangement of the street graph within an orthogonal raster grid highly distorts reality and would complicate the identification of objects in the schematic map, even if their arrangement is topologically right. For that reason we suggest to switch to a highly simplified graph which is derived from a topographic map when wanting to increase the amount of map features. Here the route does not need to consist of straight lines which are only allowed to run horizontally, vertically or at a 45°-diagonal, but can even contain curves. A completely new street graph with all crossing streets and newly located labels needs to be created for that purpose. One possibility of how to make this graph look more like a map could be to add greens, like parks or leisure areas. Usually these areas can be identified from afar and can act as landmarks which can be easily detected by pedestrians. To make this depiction look more like a city map, simplified building blocks should be included and finally all other types of details, like pavements, public transport, zebra crossings, monuments etcetera round off the picture of a clearly arranged and exhaustive map.

Hence we can conclude, that the distinction between a schematic and a topographic map is not as obvious as it seems. Many different levels of abstraction have to be passed when amplifying a schema such that a city map is derived, and it is impossible to draw a clear line that defines at which level the transformation is reached. Unfortunately it is equally difficult to evaluate on which of the described depictions a modern navigation system should be reasonably based. The following section introduces current efforts on finding answers to this question.

5 Work in progress: Evaluating the efficiency of different levels of abstraction

The purpose of this work is to rate different map types by their level of abstraction. Judging the efficiency of maps for pedestrian navigation systems and comparing them in order to find the optimal communication medium is a rather difficult task that can never lead to a simple conclusion. Many aspects influence the result of such an investigation: the user himself, his experiences and personal preferences, the complexity of the respective area, the availability of datasets, and so forth. Therefore no universal valid propositions can be made, only rough guidelines can be defined. In order to achieve that, field tests are carried out that make it possible to directly compare and evaluate the efficiency of different map types. According to the previous chapter, these depictions can be distinguished by their level of abstraction (Figures 2 - 8 show the same extract in different map types):

1. Schematic representation of the route and of crossing streets (nodes and edges) + street labels along the route
2. + street labels of crossing streets
3. Generalised street graph + street labels along the route
4. + street labels of crossing streets
5. + park areas
6. + building blocks
7. + additional map details

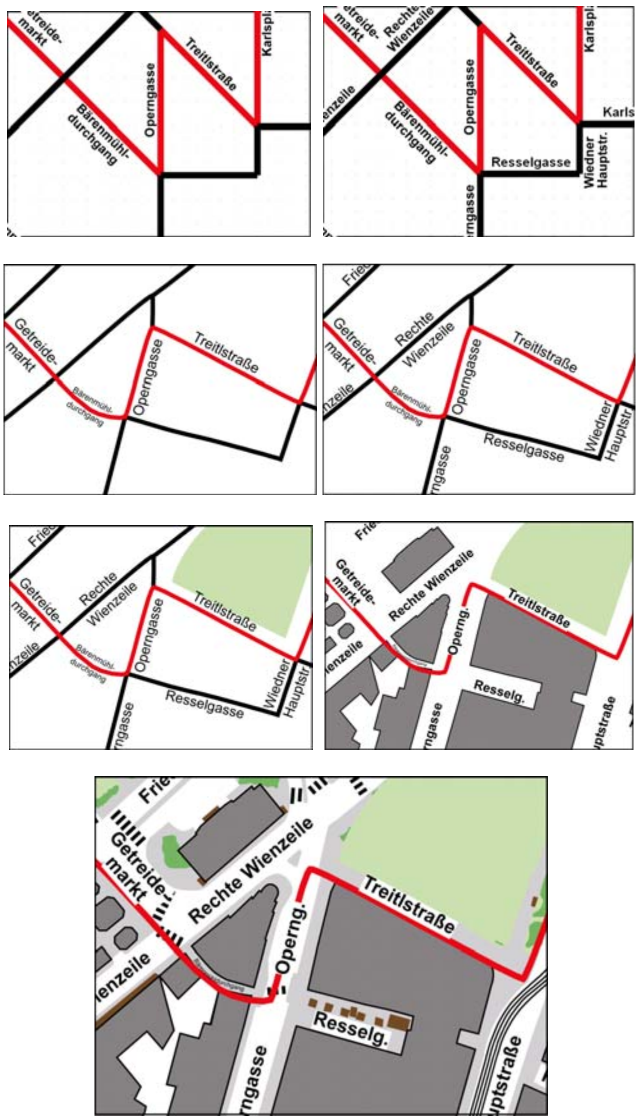

Figure 2-8: Different levels of abstractions, map types 1-7

It is possible to extend the list by 3 other types, which would only display map details that are actually bordering the route and leave out features that are located further away. Another way of focusing the attention of the user on the essential sectors could be achieved by creating buffer zones around the required route and either highlight them or blur the rest of the map, such that the user's attention cannot stroll off the route at any time. Whether this effect will be taken into consideration in a further test has not been decided yet. However, the main concept of the current field test can be described as follows:

All candidates who anticipate in the test have to follow the same route, merely the map source, which is their only guide during the trip, is chosen coincidentally. In that way a quantitative analysis could be achieved by measuring the time needed to orientate at decision points and counting the amount of errors during the task. By asking subjects to draw sketch maps of the visited area, and by comparing the results of participants who followed different map sources, conclusions about their effectiveness when generating cognitive maps can be drawn qualitatively.

The route which should be followed by participants was not chosen accidentally but should follow certain principles:

- The start of the route is placed at a prominent Viennese location, the "Opera House", which could be easily found by people, who are not at all familiar with the city.
- Maps do not give any information about subway systems along the route. Nevertheless, these underpasses are sometimes the obvious choice for pedestrians.
- In places street signs are missing or hard to find.
- A passageway for pedestrians only is included in the path.
- When crossing a market, an unnamed street has to be followed for a few meters.
- The user reaches streets which change their names along the way.
- The target building, which is currently under construction, is a university building, where subjects could rest and fill out a questionnaire.
- Altogether the walk should take no longer than 30 minutes.

All the preliminary work for the test has been realized already. An empiric questionnaire, which should give further insight on the subject's difficulties with staying on the right track, has been generated and shall be filled out by the candidates subsequent to the wayfinding test. So far 16 persons participated in the test, 8 of them evaluated a schematic map (Figure 2), 7 were guided with the help of a simplified street graph (Figure 4) and 1 person had to find her way with the help of a typical city map (Figure 8).

Recapitulating we can say that even though some tricky paths had to be crossed, most people got on quite well with the used map. The required time for the walk was somewhere between 20 and 30 minutes, only one person, who nearly got completely lost was on his way for about 45 minutes. Each candidate was accompanied by the test instructor, who was not allowed to help the person in any way, but followed him/her, stopped the time needed and took notes of unusual and surprising behaviour:

- At the meeting point in front of the “Opera House” in Vienna, the map was handed out to the participants and their current location and orientation was explained to them. Still 3 persons, who were not very familiar with the area, at first had difficulties to identify the starting direction of the route.

- About half of the candidates accidentally left the route at different spots, but all except one realised the mistake within 2 minutes and could easily get back on track no matter which map type their test was based on.

- Surprisingly 10 out of 16 persons used underpasses and subways in order to overcome traffic or bad weather conditions even though the used maps did not give any information about them. Some of them did know these subways beforehand and others have never seen them before in their lives. It was remarkable to find out, that none of them had orientation problems the moment they left the underground system.

- 14 participants turned and rotated the map in their hands in order to adjust the map alignment to their current walking direction. Only 2 men, one of them a local and the other a foreigner, left it northbound.

- People who are familiar with the area in question did not have any major difficulties with the schematic map as a presentation form once they got used to the unusual depiction. Only one tourist, who has never been in that area before, had major difficulties to follow the route. 2 other foreigners, who tested the street graph and the topographic map, stayed on the right track without any problems.

Subsequent to the way-finding task, subjects had to draw a sketch of the visited path. As expected, the sketches of the local people were quite precise even though most of them navigated along the route with the help of the schematic map and were all pointing northwards. The outlines of the foreigners, on the other hand, were all pointing southwards, which was the starting direction, and as expected, lacked a lot of information. Figure 9a and 9b show the topographic map, which was the information source of one of the tourists, and the sketch of the same person after the test. Here we can observe that corners are sometimes rounded and that many different angles are used to visualise intersections.

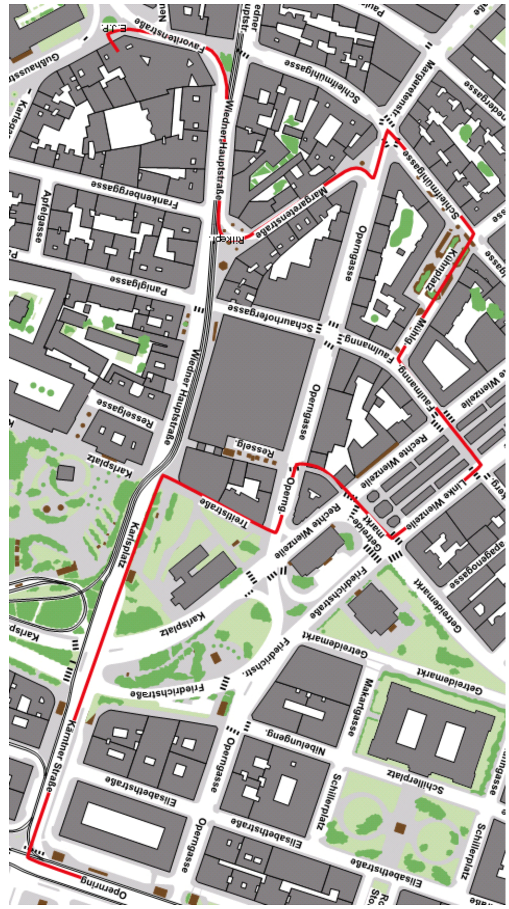

Figure 9a: Topographic map with route visualisation

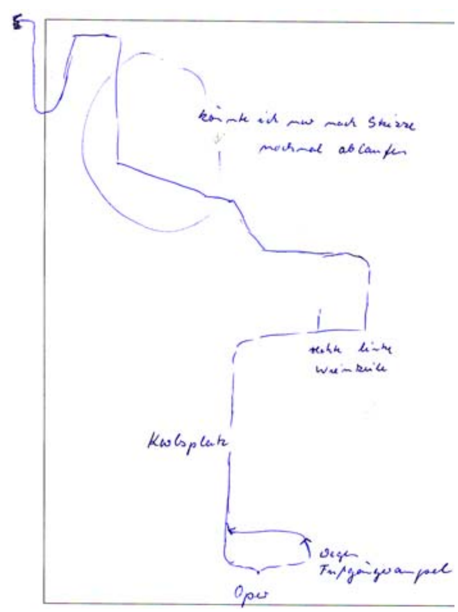

Figure 9b: Sketch of tourist after using the map of figure 9a

When looking at figures 10a and 10b, which were the source and the product of another tourist, we can observe a similar constellation. Here also a lot of detail is missing, but the streets are again curved.

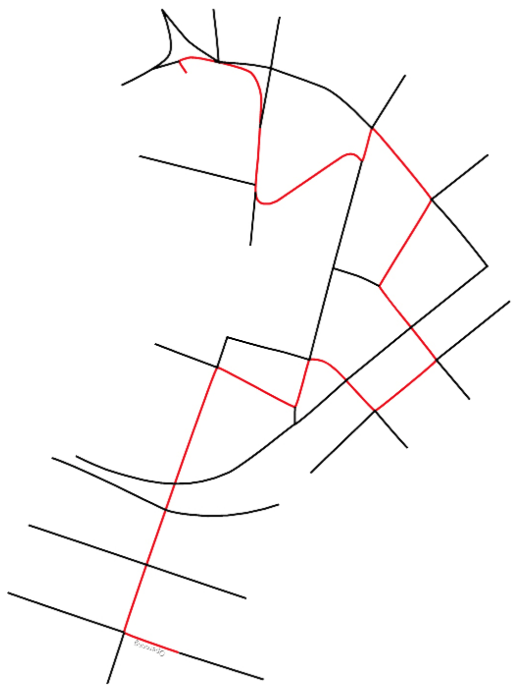

Figure 10a: Street graph

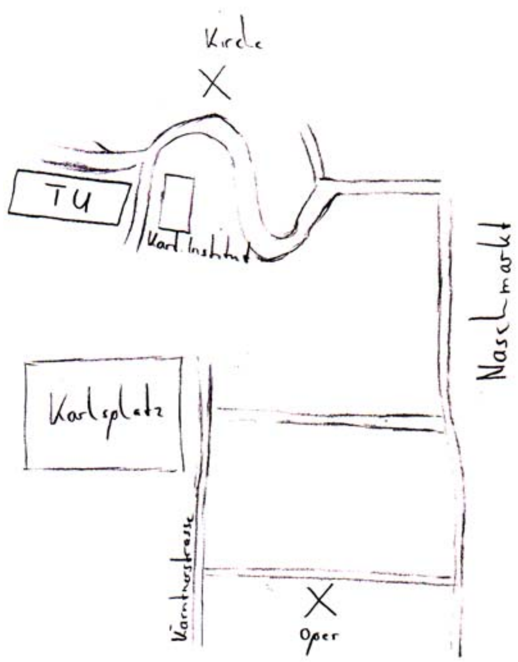

Figure 10b: Sketch of tourist after using the map of figure 10a

The most interesting figure though is the sketch of the foreigner who used the schematic map (figure 11b). Here we can clearly see the influence of the depiction, which only uses perpendicular or 45° intersections. Even a large distortion of the distance between two intersections (compare figure 11a to 10a at the top), was adopted to the sketch:

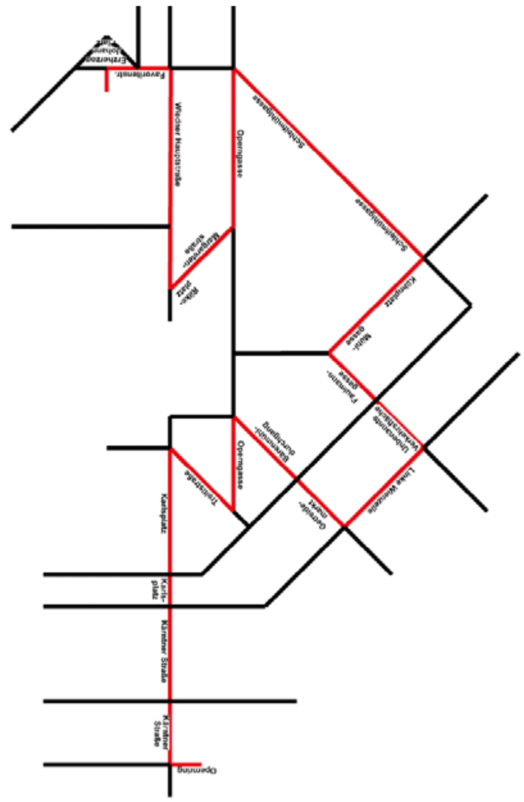

Figure 11a: Schematic map

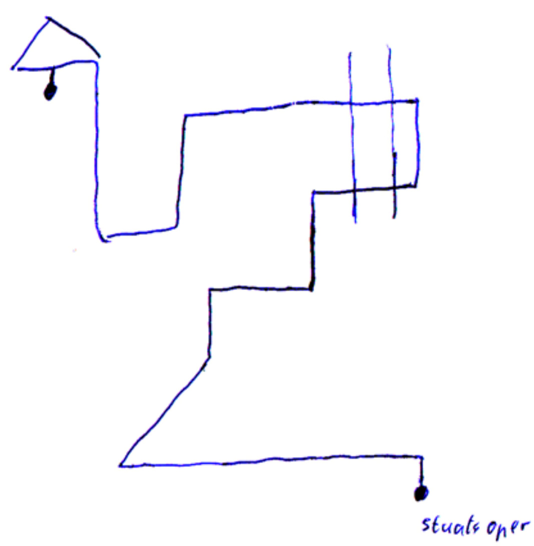

Figure 11b: Sketch of tourist after using the map of figure 11a

These results indicate, that the presentation form used when navigating along an unknown route, could highly influence the generation of the user's mental map of the environment. Further investigation on this subject will be carried out and analysed in the near future.

References:

Agrawala, M and Stolte, C. (2001): *Rendering effective route maps: Improving usability through generalization*. In: E. Fiume (Ed.), Siggraph 2001, Proceedings of the 28th Annual Conference on Computer Graphics, Los Angeles, California, USA, ACM Press, pp. 241 – 250.

Bohnenberger, T and Jameson, A. (2001): *When Policies Are Better Than Plans: Decision-Theoretic Planning of Recommendation Sequences.* In J. Lester (Ed.), IUI 2001: International Conference on Intelligent User Interfaces, New York, USA, ACM Press, pp. 21-24.

Bollmann, J., and Koch, W. G., eds. (2002): *Lexikon der Kartographie und Geomatik*. Heidelberg, Berlin: Spektrum Akademischer Verlag.

Darken, R. P., and Peterson, B. (1999): *Spatial orientation, wayfinding and representation*. In: Stanney, K. M. (Ed.): VE Handbook. Lawrence Erlbaum Associates, Inc., 1999.

Elroi, D. (1988): *GIS and Schematic Maps: A New Symbiotic Relationship*. Proceedings GIS/LIS '88, San Antonio, TX, 1988.

Iachini, T., and Logie, R. H. (2003): *The Role of Perspective in Locating Position in a Real-World, Unfamiliar Environment*. In: Applied Cognitive Psychology, 17, 2003.

Klippel, A. (1999): *Relaxierte Lokalisation - Kognitive Implikationen schematischer Karten*. In: Wachsmuth, I. & Jung, B. (Eds.), KogWis99: Proceedings der 4. Fachtagung der Gesellschaft für Kognitionswissenschaft, Bielefeld, 28. September - 1. Oktober 1999 Sankt Augustin: Infix.

Klippel, A. (2003): *Wayfinding Choremes: Conceptualizing Wayfinding and Route Direction Elements*. Doctoral dissertation, Department of Mathematics and Informatics, University of Bremen, September 2003.

Kray, C. and Elting, C., Laakso, K., Coors, V. (2003): *Presenting Route Instructions on Mobile Devices*. In: Proceedings of the International Conferences on Intelligent User Interfaces, January 12-15, 2003, Miami, FL, USA, pp. 117 – 124.

Monmonier, M. (1996): *How to lie with maps*. University of Chicago Press, 1996.

Reichl, B. (2003): *Potential verschiedener Präsentationsformen für die Vermittlung von Routeninformationen in Fußgängernavigationssystemen*. Master Thesis, Department of Cartography and Geo-Mediatechniques, Technical University, Vienna.

Thorndyke, P. W. and Hayes-Roth, B. (1982): *Differences in Spatial Knowledge Acquired from Maps and Navigation*. In: Cognitive Psychology 14, pp.560-582.